The Analysis and Prediction of Water Supply and Demand for Beijing in future

Jing Han

School of North China Electric Power University, Baoding 071003, China;

1933723786@qq.com

Abstract: The paper chooses data of the water resource supply and demand in Beijing in previous years, adopting gray correlation analysis method to analyze three main factors of water. Sequential Combination Forecasting ,Grey Forecasting and polynomial fitting method are respectively used to predict changes   of three main factors in the future .Finally, according to the forecast data, the supply and demand situations of water resource and influence of   the   situations are analyzed.

1.Introduction

We choose Beijing for analysis which is a serious shortage of water resources in the city.Per capita has 366.8 cubic meters of water per year, accounting for only 13.8% of the national average, in the capital of the world's 120 countries after a hundred. With the development of economy and the improvement of living standard, the demand of water resources is increasing. At the same time, there are serious groundwater overdraft, serious water pollution, waste and other phenomena, the contradiction between supply and demand of water resources is even more acute. Next we analyze and explain why and how water is scarce in Beijing. Besides, we predict the supply and demand of water resource in Beijing in future.

2.Reason of water shortage

2.1 Analysis of Supply and Demand of Water Resources

A regional water supply includes utilizable precipitation, renewable water, water diversion project, groundwater exploitation, entry water and other five aspects. They are defined as :

Utilizable precipitation : X_1

Renewable water : X_2

Water diversion project : X_3

Inflows of rivers : X_4

A regional water demand includes four parts: domestic water, industrial water, agricultural water and environmental water. They are defined as :

Domestic water : X_5

Industrial water : X_6

Environmental water : X_7

Agricultural water : X_8

2.2 The gray correlation analysis method

The gray correlation analysis method is a multivariate statistical analysis method. It is based on the sample data of each factor to describe the relationship between the factors by using the gray correlation degree.

The steps of Grey Relational Analysis are as follows:

1) Determine the evaluation objects (comparative series) and the reference sequences.Assume the number of the evaluation objects is m ; the number of the evaluation indexes is n ; the reference sequence is

$$z_0 = \{z_0(k) \mid k = 1,2,...,n\}$$

The evaluation objects are $z_i = \{z_i(k) \mid k = 1,2,...,n\}, i = 1,2,...,m$.

2) Determine weight of each index value $w = [w_1,...,w_n]$.

3) Calculate Grey correlation coefficient:

The correlation coefficient of the evaluation objects to the k_{th} index of the reference sequence is

$$\xi_i(k) = \frac{\min\limits_s \min\limits_t |z_0(t) - z_s(t)| + \rho \max\limits_s \max\limits_t |z_0(t) - z_s(t)|}{z_0(k) - z_i(k)| + \rho \max\limits_s \max\limits_t |z_0(t) - z_s(t)|}.$$

resolution coefficient is $\rho \in [0,1]$.

Generally, resolution coefficient and resolution ratio are positive correlation.

4) Calculate grey weighted relation. The calculating formula of grey weighted relation is:

$$r_i = \sum_{k=1}^{n} w_k \xi_i(k).$$

Grey weighted relation of the k_{th} evaluation object for the reference sequence is r_i.

5) Evaluate and analyze. According to the value of the grey weighted relation, the order of the relation of the evaluation objects can be established. The more relation, the greater evaluate.

2.3 Simulation

1) The annual water shortage in this region from 2001 to 2014 is considered as z_0.

Table1：annual Water Shortage in Beijing

Year	2001	2002	2003	2004	2005	2006	2007
Water Shortage /10^8*m^3	14.59	15.9	11.12	4.88	1.61	1.55	0
Year	2008	2009	2010	2011	2012	2013	2014
Water Shortage /10^8*m^3	0	0	0	0	0	0	1.61

2) Supply and demand of water are considered evaluation objects z_i, including amount of utilizable precipitation, renewable water, water-transfer, agricultural water, industrial water, living water, environmental water. Years are defined 14 evaluation indexes. Resolution coefficient defined ρ is equal to 0.5. Assume that the weights are equal to each index, that is, weight matrix as $w = [1/14,...,1/14]$. Due to differences of dimensions of evaluation objects, data is needed be normalized. According to the above mentioned the steps of Grey Relational Analysis, the relation between the reference sequence and the evaluation objects can be obtained as following chart:

Table2：the Relation between the Evaluation Objects and the Reference Sequences

Evaluation Objects	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Relation	0.5385	0.7534	0.7854	0.8055	0.7126	0.8047	0.650	0.7985

3) The conclusion from relation matrix: $r_4 > r_6 > r_7 > r_3 > r_2 > r_8 > r_5 > r_1$. The relation of agricultural water, industrial water respectively and water shortage is more than 80%. The three factors mainly result in water shortage in this region.

3. Prediction of water resource in the future

We choose three the highest relation from above eight factors ,respectively inflows of rivers,industrial water, environmental water, to predict their changes in next 5 years.

3.1 Sequential Combination Forecasting Model

If a region in the near future has no much changes of water conservancy project, the significant features of the change of the annual inflows of rivers in the next short term will be in the mean fluctuation. The inflows of rivers forecasting model adopts sequential combination forecasting based on mean generation function based on the mean generation function, which includes the mean function, the periodic extension matrix and the Schmidt quadrature method. Sequential Combination Forecasting Model is used to predict the inflows of rivers, and the results are as follows:
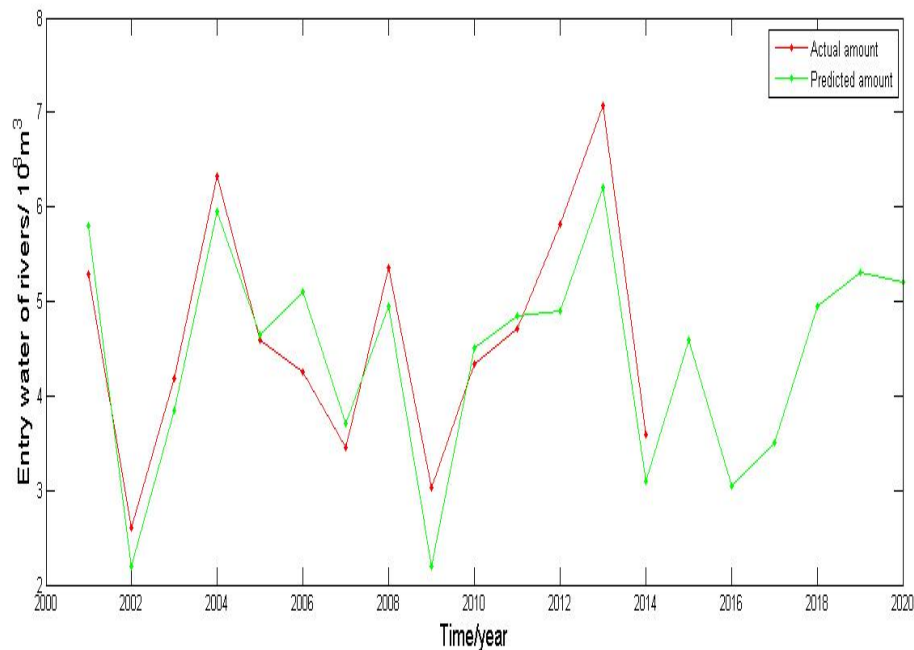

Figure 1 :Forecasting of Inflows of Rivers

3.2 Grey Forecasting Model

Grey system theory regards all random variables as grey numbers, and it is not to find the statistical law or the statistical distribution, but to use the data processing method to excavate the law between the data.

1) Gray prediction method is used to predict the industrial water consumption, and the results are as follows:
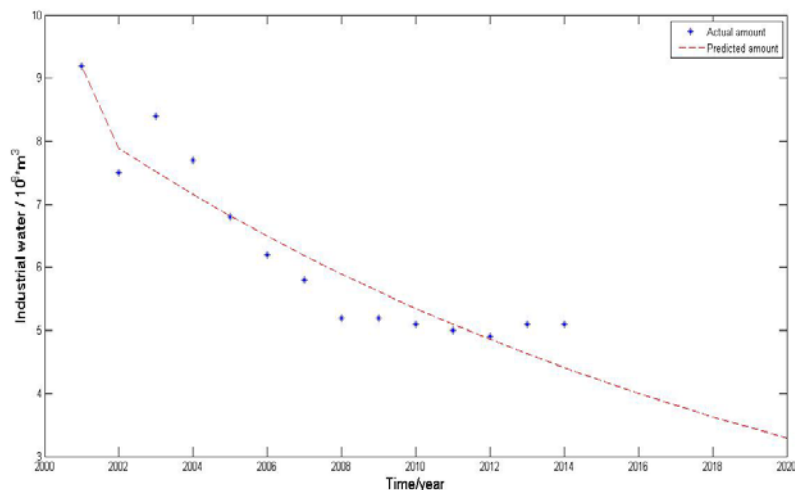

Figure 2 :Forecasting of Industrial Water

2) Gray prediction method is used to predict the environmental water, and the results are as follows:
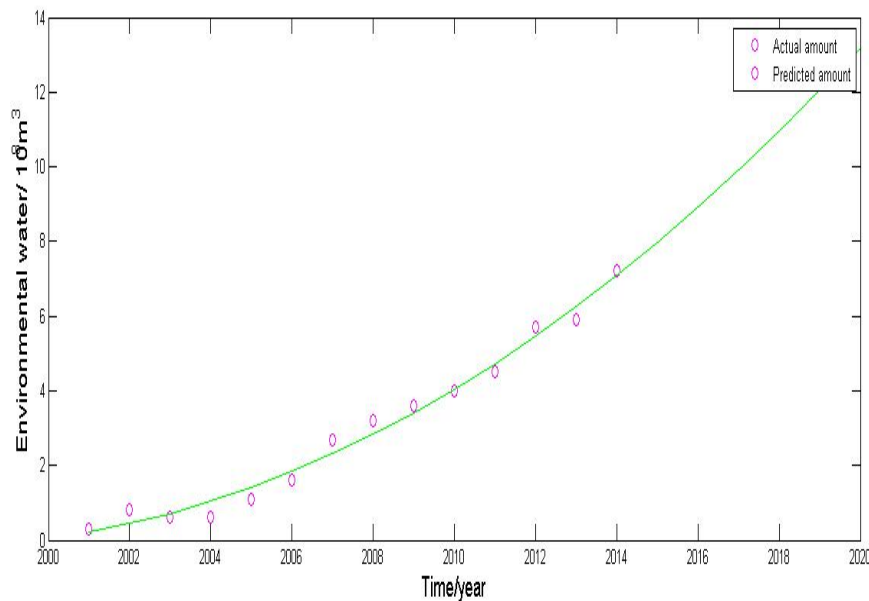

Figure 3:Forecasting of Environmental Water

4. Summary

In the next 5 years, inflows of rivers of Beijing city will be still in the wave dynamic potential and not drastic changes. Industrial water will decrease while environmental water will increase and the upward trend is large year by year. There will be no good solution to   resolve to water shortage, and the situations of supply and demand of water resource will be not still optimistic in Beijing   in the future.

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